From the Author.

27.

Contributions from the Physiological Laboratory of Yale College.

II.

ON THE INFLUENCE OF MENTAL ACTIVITY ON THE EXCRETION OF PHOSPHORIC ACID BY THE KIDNEYS.

(SILLIMAN PRIZE THESIS.)

By LUTHER HODGES WOOD, Ph.B., M. D.

[From the Proceedings of the Connecticut Medical Society, 1869.]

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[From the Proceedings of the Connecticut Medical Society, 1869.]

RESEARCHES

ON THE INFLUENCE OF MENTAL ACTIVITY

UPON THE EXCRETION OF PHOSPHORIC ACID BY THE KIDNEYS.*

BY LUTHER HODGES WOOD, PH.B., M.D., OF NEW HAVEN.

In July, 1867, Dr. T. R. Noyes presented to the Examining Committee and Faculty of this College an Inaugural Thesis upon the Excretion of Urea.† In that paper he described certain experiments instituted to ascertain the effect of sleep on this excretion. Among other results he found that the urine of the day was uniformly alkaline, and that of the night as uniformly acid; and this, even when the diet consisted of two precisely similar meals taken twelve hours apart. To account for this fact he suggested "that the causes of acidity were operating in both periods, and that the great increase of alkaline phosphates in the daytime overbalanced the acid reaction thus produced." It was to confirm or refute this hypothesis of Dr. Noyes, that the following investigation of the subject was undertaken.

The experiments here enumerated were all made upon myself, aged 21, weighing 56 kilograms, and in a good state of health.

It is evident at the outset that the difficulties to be overcome in order to change perfectly the mental condition from activity to inactivity, are necessarily very great; and hence, that the results of such experiments are liable to many sources of error. In fact, it is difficult to obtain a state of complete mental inactivity; since the mind must always be more or less active during waking hours. By removing as much as possible all the causes for mental exertion, however, on the one hand, and by actively engaging in study, on the other, the mental condition in these experiments has been very greatly varied. But on taking into consideration the many difficulties in the way of a satisfactory result, we thought it best to make three separate series of experiments, each somewhat different from the others in detail, while we endeavored in all to obtain the extremes of brain work.

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* [The writer of this Thesis received the Silliman Prize of Fifty Dollars at the Examination for Degrees at the Medical Institution of Yale College, January 14th, 1869, and the thesis was, by the Examining Committee, recommended for publication in the Proceedings of the Connecticut Medical Society. An abstract of the thesis was read in the Convention, May 25th, 1869, by Prof. G. F. Barker, M. D., and its publication was directed by the Convention.—M. C. W., Sec. Conn. Med. Soc.]

† American Journal Medical Sciences, October, 1867.

The phosphoric acid (P_2O_5) was estimated by a standard solution of uranic acetate as proposed by Neubauer.* This process is based upon the fact that uranic phosphate is insoluble in a solution containing sodic acetate and acidified by acetic acid. The minutest amount of the solution of uranic acetate in excess, therefore, gives, when a drop of a solution of potassic ferrocyanide is added to a drop of the solution, a reddish brown precipitate of uranic ferrocyanide. This process admits of very great delicacy—a single drop of uranic acetate added in excess to 50 cubic centimeters of urine being sufficient to give the color distinctly.

After determining the total phosphoric acid, the earthy phosphates in a second portion of the urine were precipitated by ammonia. The precipitate was washed as usual, and the washings added to the filtrate, which of course contained the alkaline phosphates. The phosphoric acid in the latter was then estimated in the manner described for the total phosphoric acid. The difference between the amount of total phosphoric acid and that estimated as alkaline phosphate gives the amount existing as earthy phosphate.

The solids were computed from the specific gravity according to the formula of Christison. The excess of density above 1000 multiplied by 2.33 gives the amount of solids in 1000 parts of the urine. Then, by a simple proportion we obtain the amount of solids in any given amount of this fluid.

The quantity of urine is given in the Tables in cubic centimeters; the amount of phosphoric acid excreted per hour is expressed in milligrams. The amount of phosphorus is given as phosphoric acid (P_2O_5) whether it be excreted in combination with alkalies, alkaline earths or both together. In the experiments of the first four Tables, the twenty-four hours were divided into four periods: two of six hours each for the day, and two periods of four and eight hours respectively for the night. In the 5th and 6th Tables the twenty-four hours were divided into four equal periods, each being six hours. The last two experiments were made upon the urine of the day and of the night as a whole, making but two periods of twelve hours each.

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* Analyse des Harns, by Neubauer & Vogel. 4th Edition, Wiesbaden, 1863, p. 148.

During the first period of seven days the diet was an ordinary mixed one, and the amount of study moderate. The results are given in Table (1). During the second period the amount of study was the same as in the first, but the diet was a stated one. Two meals a day were taken, at 7½ A. M. and 7½ P. M.; each meal consisted of—

Bread	1½ oz.	=	42.45 grams.
Beef	1½ "	=	42.45 "
2 Eggs	3½ "	=	99.05 "
Butter	¼ "	=	7.08 "
Potato	1½ "	=	42.45 "
Water	12 "	=	339.60 "
	20¼ oz.	=	573.08 grams.

The results of this period are given in Table (2).

The change from an ordinary mixed diet, consisting of three meals a day, of the first week, to a diet of but two meals, twelve hours apart, though alike both in quantity and kind of food taken, during the second week, produced a slight feeling of malaise, and some constipation.

This stated diet was continued during the periods given in Tables (3) and (4) but the amount of study was varied. First, it was increased about four hours a day above the amount in the previous periods; the result of this change is given in Table (3). Then. both study and recitations were entirely discontinued, and various means of recreation, requiring little or no mental effort, were substituted. The effect of this diminished study is given in Table (4).

In September the experiments upon the influence of mental labor were repeated; and as before, a regular diet, consisting of two meals a day, twelve hours apart, was adopted. Each meal now consisted of—

Beef	4 oz.	=	113.2 grams.
Bread	4 "	=	113.2 "
Beets	1 "	=	28.3 "
Water	16 "	=	452.8 "
	25 oz.	=	707.5 grams.

During the first period—the results of which are given in Table (5)—the time of study was greatly increased above the accustomed amount. During the second period—given in Table (6)—all study was abandoned, and the time spent in recreation.

This experiment was again repeated in November. Table (7) gives the excretion during the period of greatest mental activity. I was at that time attending lectures and recitations during six hours each day, and was engaged in hard study for an average of three hours a day in addition. The last four days were taken as vacation and the time was devoted to pleasure and rest from study. The effect of this period is given in Table (8).

Table (9) is a summary of the averages of the whole series of experiments; the day being divided into two periods of twelve hours each, thus making the whole average agree with the last experiments.

On comparing Tables (1) and (2), in which the amount of study was essentially the same, but the diet was different—being the ordinary one of three meals a day in the first, and in the second, consisting of two precisely similar meals taken twelve hours apart—it appears that there is in each a considerable variation in the amount of phosphoric acid excreted from day to day; and this whether the quantity be considered as a whole, or viewed as separate portions in combination with alkaline or with earthy bases.

In the first period the alkaline phosphates are most abundant in the afternoon, and steadily decrease till the morning, when the average appears to be less than in any other portion of the day.

The earthy phosphates are present in the greatest quantity during the hours of the forenoon, and are least during that portion of the night which is spent in sleep. In the second period, the alkaline phosphates average rather more during the forenoon than during any other part of the day. This seems to be an exception to the general rule, however, for in each of the other periods, this exacerbation appears later in the day. The earthy phosphates are in largest quantity during the evening, and least during the hours of sleep.

The excretion of phosphoric acid appears to be much more regular when the diet is regular, than when it is subject to the variations of the ordinary mixed diet.

The results, when the amount of time spent in hard study was much increased above the amount usually so employed, are given in Table (3); the diet being the same as in Table (2). While in Table (4), the opposite condition was present—all study and other causes of mental exertion being avoided.

Comparing these two Tables, it will be noticed that the *alkaline* phosphates are in larger amount when the study is increased, the difference being about 15 per cent; this increase taking place in the daytime, while during the night the average is rather less. The amount of *earthy* phosphates is greatest when there is no study, the increase being about the same day and night, and amounting to about·20 per cent. The *total* phosphates do not differ materially in the two Tables; though their amount is somewhat more in the one in which there is most study.

Tables (5) and (6) represent essentially the results of the same conditions as the two which precede it, Table (5) being the period of mental labor, and Table (6) the one of mental relaxation. The earthy phosphates, as in the preceding experiments, are increased during the period of mental relaxation; though the difference is greater than before, the increase being about 40 per cent during the day, and about 20 per cent during the night.

The amount of exercise taken was about the same in each of these periods; as also was the amount of sleep, which was about eight hours in the twenty-four. The only difference in the conditions was the amount of study. During the periods of greatest mental work, six hours were devoted to hard study and two hours to recitation each day, while during the periods of rest, all study and recitation were abandoned, and the time, which had been before given to these, was spent in recreation and amusement, thus producing much difference in the activity of the mind.

In both instances, increased work diminished the excretion of earthy phosphates. The alkaline phosphates were increased in the first period of study, and not altered in the second. Thus making the total amount of phosphoric acid excreted about the same, whether the mind be active or not.

The experiments recorded in Tables (7) and (8) were conducted upon an ordinary mixed diet. During the first four days, Table (7), six hours each day were spent attending lectures and recitations, and an average of three hours more devoted to hard study. The last four days, Table (8), were during vacation, and the time was spent in amusement and recreation, the amount of sleep, as before, being eight hours. By thus diminishing the mental labor, the earthy phosphates are increased 20 per cent. during the day, and 12 per cent. during the night, While under these conditions, the alkaline phosphates are diminished 15 per cent. during the day, and remain the same during the night.

Comparing the last six tables, which give the results of the three series of experiments, with each other, they are found to have the following results in common: 1st, The amount of *earthy* phosphates excreted is smallest during the periods of study, the difference being from 20 to 40 per cent. during the day, and from 12 to 20 per cent. during the night. 2d, The *alkaline* phosphates do not follow so constantly the same law in each case, yet they always vary in the same direction. They increase on increasing the amount of study in the first and third series, and in the second series are not altered, as the increase during the first part of the day is made up during the afternoon; and as the increase during the evening equals the decrease of the night. The average increase is about 15 per cent. during the day; but no change appears during the night.

The total amount of phosphoric acid is irregular, being sometimes more and at others less, during the periods of study; this amount being evidently the *mean* of the variations of the alkaline and earthy phosphates.

The most marked result obtained in these experiments, is the *great increase* of *earthy* phosphates whenever mental activity is *diminished.* This fact is constant in the whole series. Both nervous and cerebral tissue are rich in phosphorus, and this when oxidized will yield phosphoric acid; hence, *cœteris paribus,* most phosphoric acid will be found in the blood, and consequently in the urine, when these tissues are most rapidly undergoing oxidation. From this it follows that if increased activity of the organs containing these tissues, gives rise to increased disintegration and oxidation of them, the products of this oxidation would be increased in the urine; and hence, that the total phosphoric acid would be thus increased. But on the contrary if this activity consists in a more rapid growth and less decay of these tissues, then there would be found less phosphoric acid in the urine. The total amount of phosphoric acid excreted, however, does not appear, in these experiments, to be altered by changing the mental condition, sufficiently to draw any positive conclusions; but when it is separated according to whether it is combined with alkaline or with earthy bases, we find it to be greatly varied by changing the amount of brain work. If we assume that the *alkaline* phosphates result from this metamorphosis, then, since they are increased by study, the disintegration of nervous tissue would be correspondingly *increased;* while if the *earthy* phosphates have this origin, then, as they are *diminished* under these circumstances, there must be *less* oxidation of these tissues when the mind is actively engaged. Consequently it would follow that the same law which the researches of Dr. Noyes and Dr. Parkes have shown to be true of muscular tissue, namely, that it grows during a state of active exercise, is true also of nervous tissue.

Now, inasmuch as the alkaline phosphates are not increased in any proportion to the amount of increase of mental labor; while the earthy phosphates are diminished in a very much greater proportion by the same means; it seems probable that the latter of these hypotheses—that mental labor diminishes the amount of earthy phosphates excreted, and consequently that nervous tissue grows when in a state of activity—is the true one.

Dr. W. A. Hammond has published in his "Physiological Memoirs" the results of a series of analyses undertaken to determine the law of the excretion of phosphoric acid. He finds that the amount which is excreted is greatly increased on increasing the amount of study; though he only estimated the total amount of phosphoric acid, without distinguishing it according to the bases with which it was combined. Moreover his determinations were made by Liebig's method, with ferric chloride. From the results of his experiments he argues* that "the brain is seen to follow the same general law which governs the other structures of the body—increased use promotes increased decay," "intense mental labor, by accelerating the metamorphosis of the cerebral tissue, necessarily requires a renewal of that tissue, and thus the nutrient elements of the food are diverted from those parts of the body by which they would ordinarily be appropriated to that organ which so imperatively demands them." It will be seen, from what has been already stated, that my results do not agree with those of Dr. Hammond, though all the series here given agree well among themselves; indeed so far as any inference can be drawn, they prove just the opposite.

Mosler also, has made some experiments on the same subject,† in which he separated the phosphates of the earths from those of the alkalies. He found that increased study increased the total phosphoric acid one half, the alkaline phosphates less than one quarter, and the earthy phosphates one third; though how the former fact can be derived from the two latter and constituent facts, does not appear.

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* Hammond's Physiological Memoirs, Philad., 1863, page 23.

† Inaug. Diss., Giessen, 1853.

It is possible that in the experiments of Hammond and of Mosler, the mental exertion was carried to the point of fatigue, which is not true of any of the experiments recorded in this paper. If that were the case, the fact would be another link in the chain of evidence that nervous tissue follows the law governing the action of muscular tissue; and that, just as the latter, as Dr. Noyes has shown, produces an increased amount of urea in the urine only when exercised beyond the point of fatigue, so the former gives under the same conditions only, an increased excretion of phosphates.

In regard to the question whether the alkalinity of the day-urine is due to the presence of alkaline phosphates as was suggested by Dr. Noyes, it is evident that the fact that this alkalinity is found uniformly in the forenoon when the amount of alkaline phosphates is less than in any other period of the day, a fact established by my analyses, proves this conjecture to be unfounded. This fact, however, does not throw any light upon the real cause of the alkalinity. Why should it appear only in the urine passed at 1 P. M., the period which immediately follows the concentrated acid urine of the night? And this when the quantity of solids is least in proportion to the quantity of water? Moreover, why should not the urine passed at 1 A. M., a period of the day corresponding in all respects with the former, be also alkaline? Does not the fact seem to point to a tissue change either destructive or assimilative, which takes place during sleep, the products of which are excreted a few hours after rising?

The results obtained in the foregoing research may be thus summed up:—

1. The *amount of urine* excreted varies at different periods of the day, even on a fixed diet; the day-urine exceeds the night-urine in the ratio of 3 to 2. The largest amount is excreted during the forenoon, the next largest in the afternoon, then comes that of the latter part of the night, and lastly that passed in the early part of the night.

2. The *density* of the urine varies inversely as the amount of urine passed; the morning-urine having a higher specific gravity than that excreted at night.

3. The *total amount of solids* excreted is greater during the day than during the night by nearly 50 per cent.; thus showing that

the density is not diminished in proportion to the amount of urine passed.

4. The *reaction* of the day-urine is uniformly alkaline, that of the night-urine acid; while however, acid urine is excreted during both periods of the night, it is the morning-urine only that is alkaline, that of the afternoon being acid.

5. The total *phosphoric acid* excreted per hour on an ordinary diet, is largest during the day, rising highest after the principal meal; while on a fixed diet, the excretion is greatest at night, the maximum being reached during the first half of the night, the amount diminishing in the afternoon; it is less still at 7 A. M. and least at 1 P. M.

6. The *alkaline phosphates*, when an ordinary diet is taken, are greater by day than by night; on a fixed diet the reverse is true.

7. The *earthy phosphates*, on the other hand, are largest in amount during the day, both on ordinary and fixed diets.

8. The *total phosphoric acid* is very greatly affected by the amount and kind of food taken.

9. The *variations* in the amount of phosphoric acid, considered as a whole, are not sufficient to afford any indication of the previous mental condition.

10. The *alkaline phosphates* are only *slightly increased* on increasing the amount of mental labor.

11. The *earthy phosphates* are *diminished* under the same conditions, by an amount varying from 20 to 40 per cent.

12. *No such increase of phosphoric acid* as would be required by the theory of the disintegration of nervous tissue during action, was observed in these experiments.

13. The *alkalinity* of the day-urine is not due to the presence of alkaline phosphates in excess.

The results given in figures in the tables, are plotted in a series of nine diagrams appended to this thesis. They are intended to illustrate more clearly all the variations in the excretion of phosphoric acid,—whether considered as a whole, or divided according to its combination with alkaline and earthy bases,—which I have observed as a result of my analyses.

On the margin of these diagrams, the day and hour at which the urine was voided, are indicated. The number of milligrams excreted per hour, is given at the left-hand margin, the scale beginning at 0, and extending to 100. The line which represents the excretion differs for the different forms under which the phosphoric acid existed; the alkaline phosphates being indicated by a straight line, thus :————: the earthy phosphates by a broken line ....: while the total phosphoric acid is denoted by an interrupted line like this: — — ——— — ———:

Two important facts are made apparent upon studying these diagrams. One is the great variation in each of the lines from one period to another of the same day; from which it is evident that the analyses should be made upon urine taken at equal intervals during the day. A second fact is that the variations in the total phosphoric acid, being the sum of the variations of its two forms of combination, do not at all indicate the amount of the variation of these latter; and hence that the analyses should include the determination of both alkaline and earthy phosphates.

The effect produced by changing the mental condition is exhibited more markedly in the ninth diagram, which shows the variation in the excretion for each week during each of the three series of experiments.

In conclusion, I would express my sincere thanks to Prof. George F. Barker, M.D., for many valuable suggestions, made during the progress of these researches in the Laboratory of the Medical College.

TABLE No. 1.—ORDINARY MIXED DIET, MODERATE STUDY.

	1 P. M.								7 P. M.							
Date.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. acid.	Total Solids.
May.	c.c.				Milligrams Per hour.			Grams.	c.c.				Milligrams Per hour.			Grams.
25	240	1025	Alkaline	Yellow.	33.4	32.4	66.1	13.98	145	1030	Acid	Reddish-yellow.	47.3	18.1	65.4	10.13
26	375	1019	Slig'tly acid	Yellow.	35 3	19.1	54.4	16.6	205	1020	"	" "	25.3	11.8	37.1	9.55
27	255	1020	Alkaline	Reddish-yellow.	73.9	16.	89.9	11.88	180	1028	Slightly acid	" "	62.6	19.5	82.2	11.74
28	475	1014	"	Yellow.	38.6	33.7	72.3	12 3	240	1020	" "	" "	55.6	17,4	73.	11.18
29	200	1025	"	Reddish-yellow.	26.5	25.5	52.	11.65	95	1032	Alkaline	" "	60.	15.	75.	6.98
30	215	1020	"	Yellow.	21.8	20.2	42.	10.02	165	1030	Acid	" "	91.	9.	100.	10.53
31	200	1023	"	"	45.5	25.8	71.3	10.72	200	1029	"	" "	41.	24.5	65.5	13.51
Average.	230	1021	Alkaline	Yellow.	39.3	24.7	64.	12.45	176	1027	Acid	Reddish-yellow.	54.7	16.5	71.2	10.52
	11 P. M.								7 A. M.							
May 25	85	1022	Acid	Reddish-yellow.	50.8	17.5	68.4	4.35	365	1013	Acid	Yellow.	44.8	7.6	52.4	9.49
" 26	105	1022	"	" "	38.8	16.8	55.6	5.38	357	1009	"	Light-yellow	36.9	9.7	46.6	6.48
" 27	140	1025	"	" "	59.4	19.8	79.2	8.16	375	1015	"	Yellow.	29.8	10.4	40.2	11.25
" 28	75	1027	"	" "	12.6	13.	25.6	4.72	170	1022	"	Reddish-yellow.	46.6	6.4	53.	8.71
" 29	90	1030	"	" "	39.2	23.	62.2	6.29	175	1025	"	Yellowish-red.	34.4	19.4	53.8	10.19
" 30	155	1030	"	" "	67.4	25.3	92.7	10.83	240	1023	"	Yellow.	46.	20.3	66.3	12.85
" 31	70	1030	"	" "	66.4	17.3	83.7	4.89	145	1028	"	Reddish-yellow.	44.	7.8	51.8	9.46
Average.	103	1029	Acid	Reddish-yellow.	47.9	18.9	66.8	6.37	261	1019	Acid	Yellow.	41.	11.	52.	9.77

TABLE No, 2.—REGULAR DIET, MODERATE STUDY.

	1 P. M.								7 P. M.							
Date.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.	Quantity,	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.
June.					Milligrams Per hour.			Grams.					Milligrams Per hour.			Grams.
1	420	1023	Alkaline	Reddish-yellow.	66.8	3.2	70.	21.50	105	1030	Acid.	Reddish-yellow.	34.6	28.4	63.	7.34
2	440	1022	"	Yellow.	82.1	13.4	95.5	22.55	110	1030	"	" "	63.2	8.4	71.6	7.69
3	200	1027	"	Reddish-yellow.	58.	18.	76.	12.58	115	1030	"	" "	76.5	5.5	82.	8.04
4	215	1025	"	Yellow.	57.4	17.2	74.6	12.23	90	1030	"	" "	50.6	13.4	64.	6.29
5	260	1025	"	"	61.4	16.	77.4	15.14	140	1026	"	" "	68.	10.3	78.3	8.48
Average.	306	1024	Alkaline	Yellow.	65.1	13.6	78.7	16.80	112	1029	Acid.	Reddish-yellow,	58.6	13.2	71.8	7.57
	11 P. M.								7 A. M.							
June 1	55	1031	Acid	Reddish-yellow.	51.7	6.3	58.	3.97	180	1030	Acid	Reddish-yellow.	71.8	11.6	83.4	12.59
" 2	75	1036	"	Yellowish-red.	76.7	17.9	94.6	6.29	120	1031	"	" "	60.6	7.2	67.8	8.67
" 3	90	1032	"	Reddish-yellow.	69.7	19.8	89.5	6.71	130	1029	"	Yellow.	62.1	5.2	67.3	8.78
" 4	85	1032	"	" "	53.	26.	79.	6.24	145	1030	"	Reddish-yellow.	61·2	4.3	65.5	8.14
" 5	70	1035	"	Yellowish-red.	51.4	16.3	67.7	5.7	120	1030	"	Yellowish-red.	54.	6.7	60.7	8.39
Average.	75	1033	Acid	Reddish-yellow.	60.5	17.3	77.8	5.78	139	1030	Acid	Reddish-yellow.	62.	7.	69.	9.31

TABLE No. 3.—REGULAR DIET, INCREASED STUDY.

	1 P. M.								7 P. M.							
Date.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.
June	c.c.				Milligrams Per hour.			Grams.					Milligrams Per hour.			Grams.
8	355	1021	Alkaline	Yellow.	40.2	21.8	62.	17.37	160	1030	Neutral	Reddish-yellow.	58.	16.	74.	11.18
9	250	1023	"	"	37.8	13.	50.8	13.39	150	1026	Acid	" "	49 5	16.8	66.3	9.09
10	135	1027	Acid	Reddish-yellow.	44.4	14.8	59.2	7.49	100	1030	"	" "	49.7	17.3	67.	6.99
11	280	1023	Alkaline	Yellow.	39.5	8.2	47.7	15.08	150	1033	"	" "	54.3	16.7	71.	11.53
12	240	1023	"	"	27.	15.4	42.4	12.86	130	1026	Slightly acid	Yellow.	58.2	9.7	67.9	7.87
13	235	1024	"	"	26.	20.	46.	13.14	110	1032	Acid	Reddish-yellow.	55.	16.6	71.6	8.20
Average.	247	1023	Alkaline	Yellow.	35.6	15.7	51.3	13.22	133	1029	Acid	Reddish-yellow.	54.1	15.5	69.6	9.14
	11 P. M.								7 A. M.							
June 8	70	1032	Acid	Yellowish-red.	58.7	17.5	76.2	5.22	125	1029	Acid	Yellowish-red.	56.4	7.	63.4	8.45
" 9	110	1030	"	" "	48.3	11.7	60.	7.69	75	1030	"	" "	41.9	7.8	49.7	6.21
" 10	65	1034	"	" "	53.2	17.5	70.7	5.15	140	1026	"	" "	52.2	3.2	55.4	8.48
" 11	85	1036	"	Reddish-yellow.	54.4	27.6	82.	7.13	110	1031	"	Reddish-yellow.	43.5	6.4	49.9	7.94
" 12	90	1033	"	" "	49.1	9.6	58.7	6.92	110	1025	"	" "	40.7	5.1	45.8	6.41
" 13	60	1030	"	" "	76.	18.3	94.3	4.19	125	1028	"	" "	59.	11.	70.	8.15
Average.	80	1033	Acid	Yellowish-red.	56.6	17.	73.6	6.05	114	1028	Acid	Reddish-yellow.	48.9	6.8	55.7	7.61

TABLE No. 4.—REGULAR DIET, NO STUDY.

	1 P. M.								7 P. M.							
Date.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.
June					Milligrams Per hour.			Grams.					Milligrams Per hour.			Grams.
15	175	1025	Alkaline	Reddish-yellow.	21.2	23.8	45.	10.19	85	1030	Acid	Reddish-yellow.	36.9	11.6	48.5	5.94
16	170	1026	"	" "	29.4	8.3	37.7	10.30	150	1026	"	" "	44.	21.2	65.2	9.08
17	190	1023	"	Yellow.	20.2	13.5	33.7	10.18	90	1020	"	" "	48.1	9.7	57.8	6.29
18	190	1027	"	"	30.6	15.7	46.3	11.95	115	1028	"	" "	49.7	31.5	81.2	7.30
19	205	1026	"	"	37.6	23.4	60.0	12.42	115	1032	"	" "	35.	21.	56.	8.57
Average.	146	1025	Alkaline	Yellow.	27.8	16.9	44.7	11.01	111	1029	Acid	Reddish-yellow.	42.3	19.4	61.7	7.43
	11 P. M.								7 A. M.							
June 15	65	1032	Acid	Reddish-yellow.	70.2	11.9	82.1	4.84	120	1027	Acid	Reddish-yellow.	36 6	9.9	46.5	7.55
" 16	84	1027	"	" "	50.3	8.3	58.6	5.28	125	1025	"	" "	50.	5.	55.	7.28
" 17	75	1028	"	" "	47.	7.9	54.9	4.89	95	1027	"	Yellow.	42.5	5.5	48.	5.97
" 18	95	1028	"	" "	78.3	13.3	91.6	6.19	150	1030	"	Reddish-yellow.	56.	23.	79.	10.48
" 19	75	1034	"	" "	59.7	30.	89.7	5.94	100	1034	"	" "	66.3	29.7	96.	7.92
Average.	79	1030	Acid	Reddish-yellow.	61.1	14.3	75 4	5.43	118	1029	Acid	Reddish-yellow.	50.3	14.6	64.9	7.84

TABLE No. 5.—REGULAR DIET, INCREASED STUDY.

	1 P. M.								7 P. M.							
Date.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alkaline Phos.	P_2O_5 as Earthy Phos.	Total Phos. Acid.	Total Solids.
Sept.	c.c.				Milligrams Per hour.			Grams.	c. c.				Milligrams Per hour.			Grams.
7	265	1025	Acid	Yellow.	26 4	13.6	40.	15.44	85	1030	Acid	Reddish-yellow.	13.7	6.4	20.1	5.94
8	235	1026	"	"	38.7	6.	44.7	14.24	105	1031	"	" "	32.5	8.6	41.1	7.58
9	180	1028	"	Reddish-yellow.	38.3	7.4	45.7	11 74	145	1030	"	" "	54.	8.3	62.3	10.13
10	175	1027	"	" "	28.8	9.2	38.	11.	95	1033	"	" "	41.8	5.5	47.3	7.30
11	180	1027	"	" "	39.6	9.3	48.9	11.32	90	1030	"	" "	45.	9.1	54.1	6.29
12	175	1028	"	" "	40.9	12.6	53.5	11.42	95	1030	"	" "	37.	11.3	48.3	6.64
Average.	202	1027	Acid	Reddish-yellow.	35.4	9.7	45.1	12.53	103	1031	Acid	Reddish-yellow.	37.3	8.2	45.5	7.31
	11 P. M.								7 A. M.							
Sept. 7	65	1033	Acid	Reddish-yellow.	12.3	4.2	16.5	4.99	100	1029	Acid	Reddish-yellow.	25.7	22.3	48.	6.76
" 8	90	1030	"	" "	18.2	10.2	28.4	6.29	105	1029	"	" "	36.1	7.9	44.	7.09
" 9	110	1031	"	" "	40.5	5.6	46.1	7.94	105	1028	"	" "	37.4	7.3	44.7	6.85
" 10	95	1032	"	" "	39.2	10.8	50.	7.18	115	1029	"	" "	30.8	12.7	43.5	7.77
" 11	100	1032	"	" "	33.7	14.4	48.1	7.45	115	1029	"	" "	52.9	12.8	65.7	7.77
" 12	70	1030	"	" "	19.7	13.	32.7	4.89	80	1029	"	" "	39.	6.3	45.3	5.40
Average.	88	1031	Acid	Reddish-yellow.	27.3	9.7	37.	6.46	103	1029	Acid	Reddish-yellow.	37.	11.5	48.5	6.94

TABLE No. 6.—REGULAR DIET, NO STUDY.

	1 P. M.								7 P. M.							
Date.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. acid.	Total Solids.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. acid.	Total Solids.
Sept.	c.c.				Milligrams Per hour.			Grams.					Milligrams Per hour.			Grams.
14	150	1026	Acid.	Reddish-yellow.	17.	12.9	29.9	9.08	105	1031	Acid	Reddish-yellow.	19.8	14.8	34.6	7.58
15	240	1025	"	" "	30.5	13.2	43.7	13.98	150	1029	"	" "	30.9	16.5	47.4	10.23
16	185	1028	"	" "	41.9	8.7	50.6	12.07	165	1028	"	" "	48.2	3.9	52.1	10.76
17	245	1026	"	" "	37.	6.8	43.8	14.84	235	1025	"	" "	52.5	9.7	62.2	13.68
18	185	1026	"	" "	41.3	7.6	48.9	11.21	150	1030	"	" "	47.	25.6	72.6	10.48
19	175	1027	"	" "	24.	16.9	40.9	11.	175	1028	"	" "	43.9	22.3	66.2	11.41
Average.	197	1026	Acid	Reddish-yellow.	32.	11.	43.	12.03	163	1028	Acid	Reddish-yellow.	40.4	15.4	55.8	10.69

	11 P. M.								7 A. M.							
Sept. 14	110	1031	Acid	Reddish yellow.	30.2	14.4	44.6	7.94	95	1026	Acid	Reddish-yellow.	27.7	6.9	34.6	5.75
15	95	1032	"	" "	39.2	15.	54.2	7.08	110	1030	"	" "	41.9	13.5	54.4	7.69
16	125	1030	"	" "	30.1	13.3	43.4	8.74	120	1028	"	" "	27.2	10.3	37.5	7.83
17	140	1028	"	" "	42.3	10.6	52.9	11.20	100	1029	"	" "	31.6	8.2	39.8	6.75
18	100	1034	"	" "	32.6	9.3	41.9	7.92	95	1032	"	" "	38.	12.9	50.9	7.08
19	130	1031	"	" "	31.3	23.6	54.9	9.39	120	1028	"	" "	25.2	13.6	38.8	7.83
Average.	117	1031	Acid	Reddish-yellow.	34.3	14.4	48.7	8.71	107	1029	Acid	Reddish-yellow.	31.9	10.9	42.8	7.16

TABLE No. 7.—MIXED DIET, HARD STUDY.

	7 A. M.								7 P. M.							
Date.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. acid.	Total Solids.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. acid.	Total Solids.
Nov.	c.c.				Milligrams Per hour.			Grams.					Milligrams Per hour.			Grams.
12	300	1022	Acid	Reddish-yellow.	27.7	20.4	48.1	15.38	435	1025	Alkaline.	Reddish-yellow.	38.1	26.2	64.3	25.34
13	305	1023	"	" "	35.1	17.3	52.4	16.34	380	1026	"	" "	28.4	29.1	57.5	23.02
14	205	1030	"	Yellowish-red.	28.9	14.1	43.	14.33	400	1025	"	" "	35.	21.4	56.4	23.30
15	165	1032	"	" "	34.5	13.1	47.6	12.30	280	1028	"	" "	35.6	15.9	51.5	18.26
Average.	244	1027	Acid	Reddish-yellow.	31.5	16.2	47.7	14.59	374	1026	Alkaline.	Reddish-yellow.	34.3	23.1	57.4	22.48

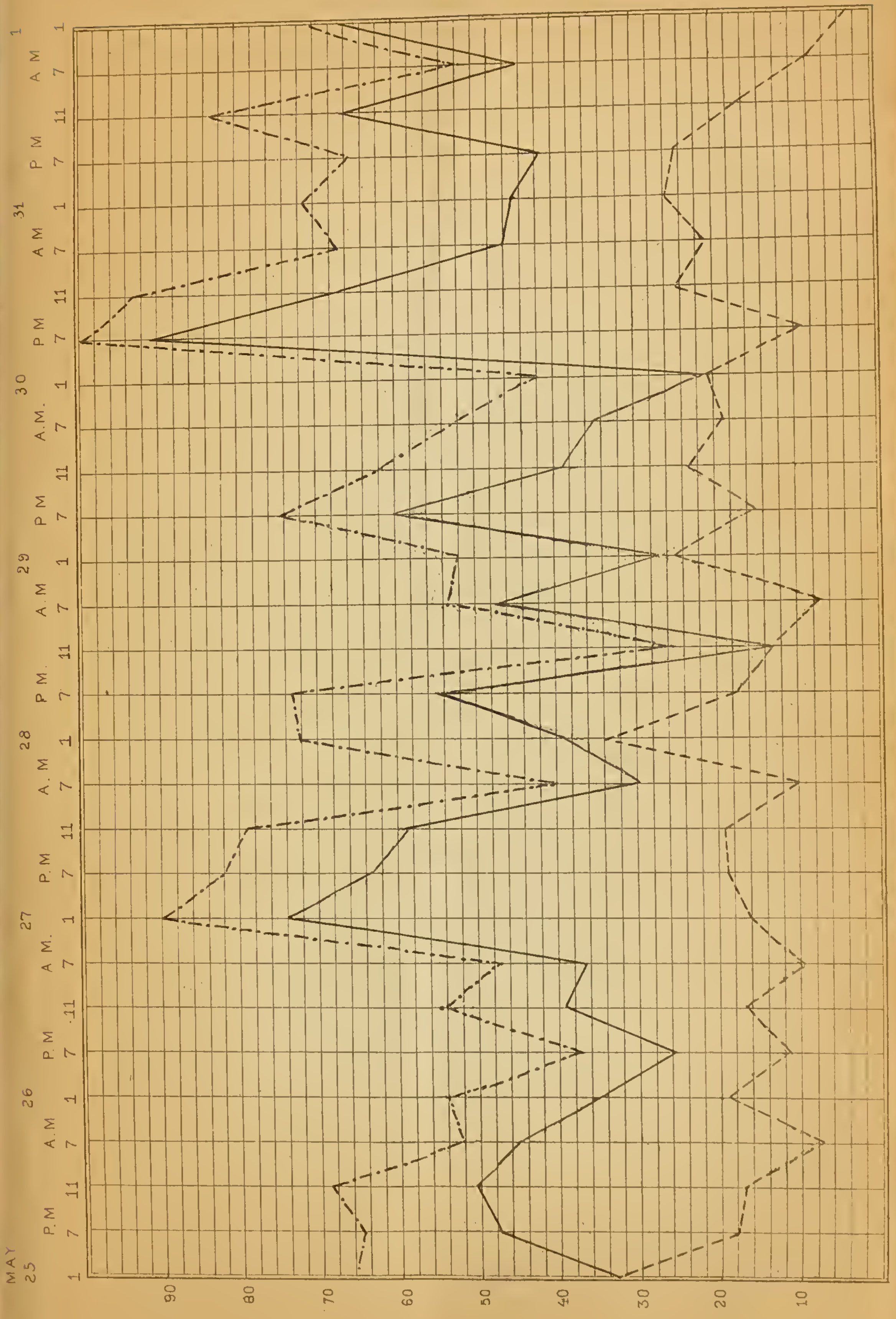
TABLE No. 8.—MIXED DIET, NO STUDY.

	7 A. M.								7 P. M.							
Nov.	c.c.															
23	160	1035	Acid	Yellowish-red.	35.	17.5	52.5	13.05	350	1030	Alkaline.	Yellow.	34.5	21.5	56.	24.46
24	245	1032	"	Reddish-yellow.	24.1	15.5	39.6	18.27	345	1031	Slightly acid	Reddish-yellow.	21.1	23.6	45.3	24.92
25	210	1026	"	" "	23.4	16.5	39.9	12.72	275	1027	Alkaline.	Yellow.	19.9	21.3	41.2	17.50
26	410	1028	"	" "	43.6	26.9	70.5	26.75	555	1022	"	"	41.5	37.	78.5	28.45
Average.	256	1030	Acid	Reddish-yellow.	31.5	29.1	50.6	17.7	381	1028	Alkaline.	Yellow.	29.4	25.8	55.2	24.33

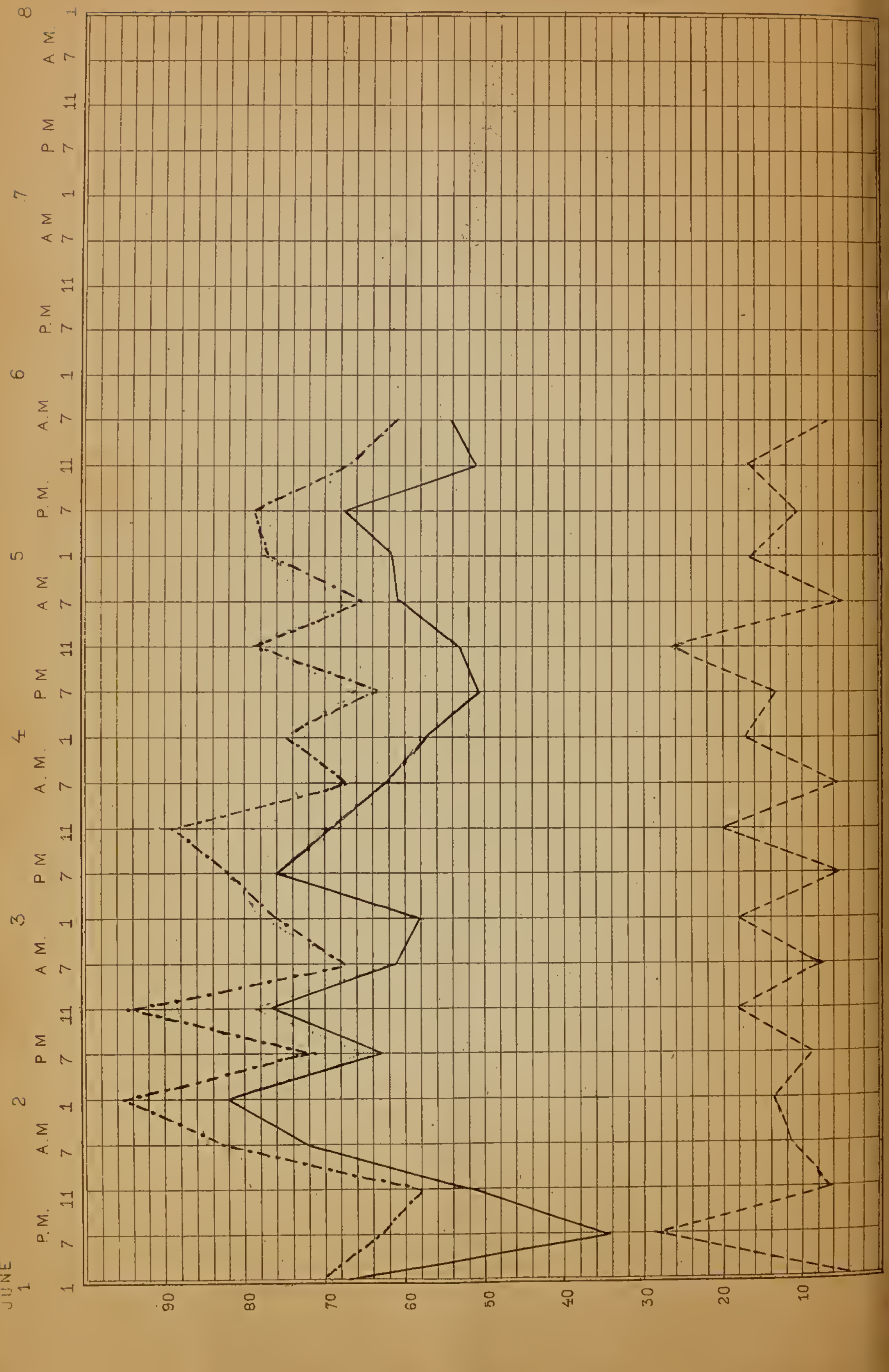
TABLE No. 9.—AVERAGE OF EACH WEEK FOR THE WHOLE SERIES.

	7 P. M.								7 A. M.							
Table.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alk. Phos.	P_2O_5 as Earthy Phos.	Total Phos. acid.	Total Solids.	Quantity.	Sp. Gr.	Reaction.	Color.	P_2O_5 as Alkaline Phos.	P_2O_5 as Earthy Phos.	Total Phos. acid.	Total Solids
					Milligrams Per hour.			Grams.					Milligrams Per hour.			Grams.
1	456	1024	Alkaline	Reddish-yellow.	47.	20.6	67.6	22.97	364	1024	Acid	Reddish-yellow.	44.5	14.9	59.4	16.14
2	438	1026	Alkaline	Reddish-yellow.	61.8	13.4	75.2	24.37	214	1031	Acid	Reddish-yellow.	61.2	12.2	73.4	15.18
3	380	1026	Alkaline	Reddish-yellow.	44.8	15.6	60.4	22.36	194	1030	Acid	Reddish-yellow.	52.7	11.9	64.6	13.66
4	257	1027	Alkaline	Reddish-yellow.	35.	18.1	53.1	18.44	197	1029	Acid	Reddish-yellow.	55.7	14.5	70.2	13.23
5	305	1029	Acid	Reddish-yellow.	36.3	8.9	45.2	19.84	191	1030	Acid	Reddish-yellow.	32.1	10.6	42.7	13.40
6	360	1027	Acid	Reddish-yellow.	36.2	13.2	49.4	22.72	224	1030	Acid	Reddish-yellow.	33.1	12.7	45.8	15.87
7	374	1026	Alkaline	Reddish-yellow.	34.3	23.1	57.4	22 48	244	1027	Acid	Yellowish-red.	31.5	16.2	47.7	14.59
8	381	1028	Alkaline	Yellow.	29.4	25.8	55.2	24.33	256	1030	Acid	Reddish-yellow.	31.5	19.1	50.6	17.7

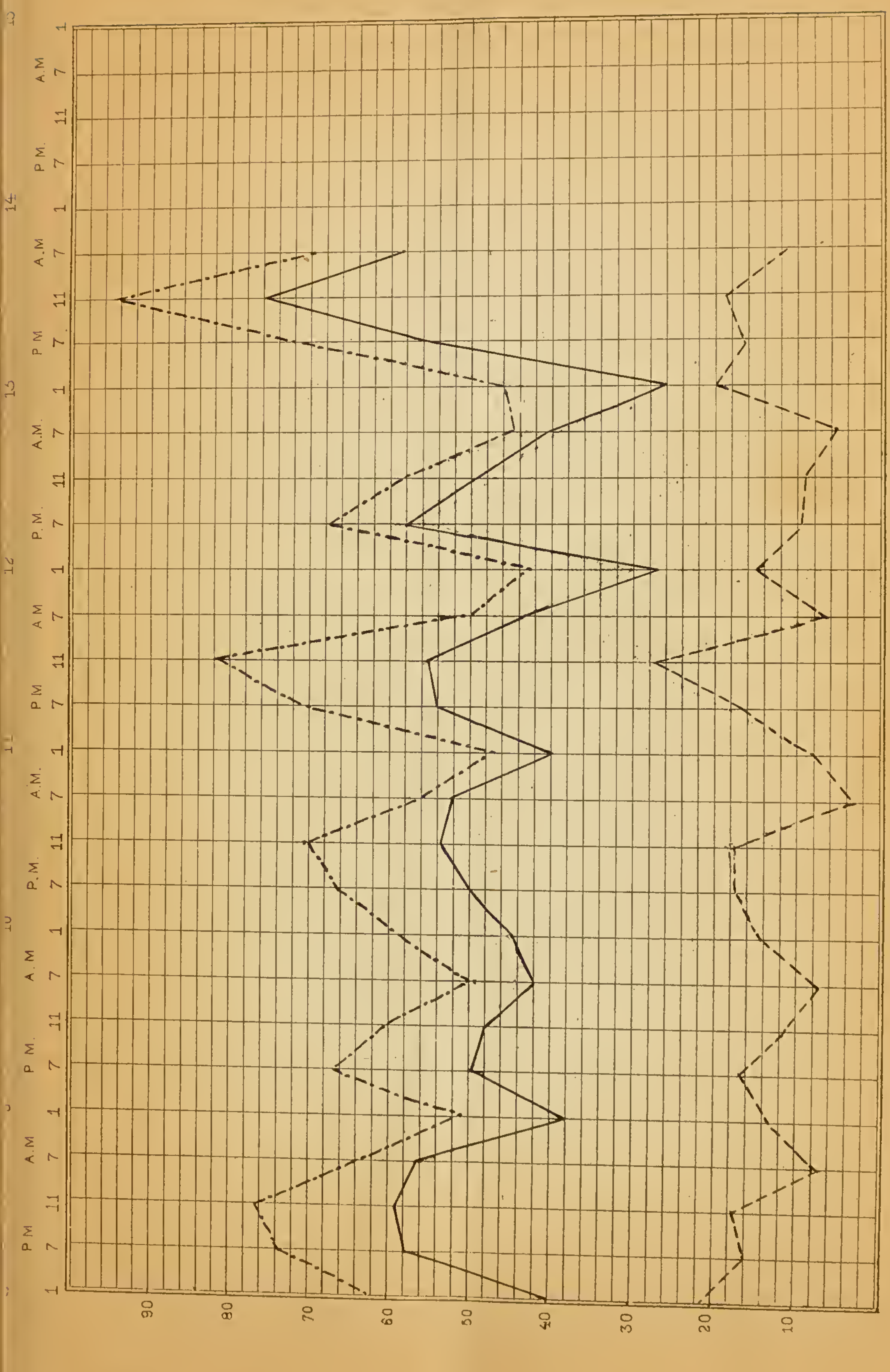
No.1 ORDINARY MIXED DIET MODERATE STUDY



No.2 REGULAR DIET, MODERATE STUDY



No 3. REGULAR DIET, INCREASED STUDY



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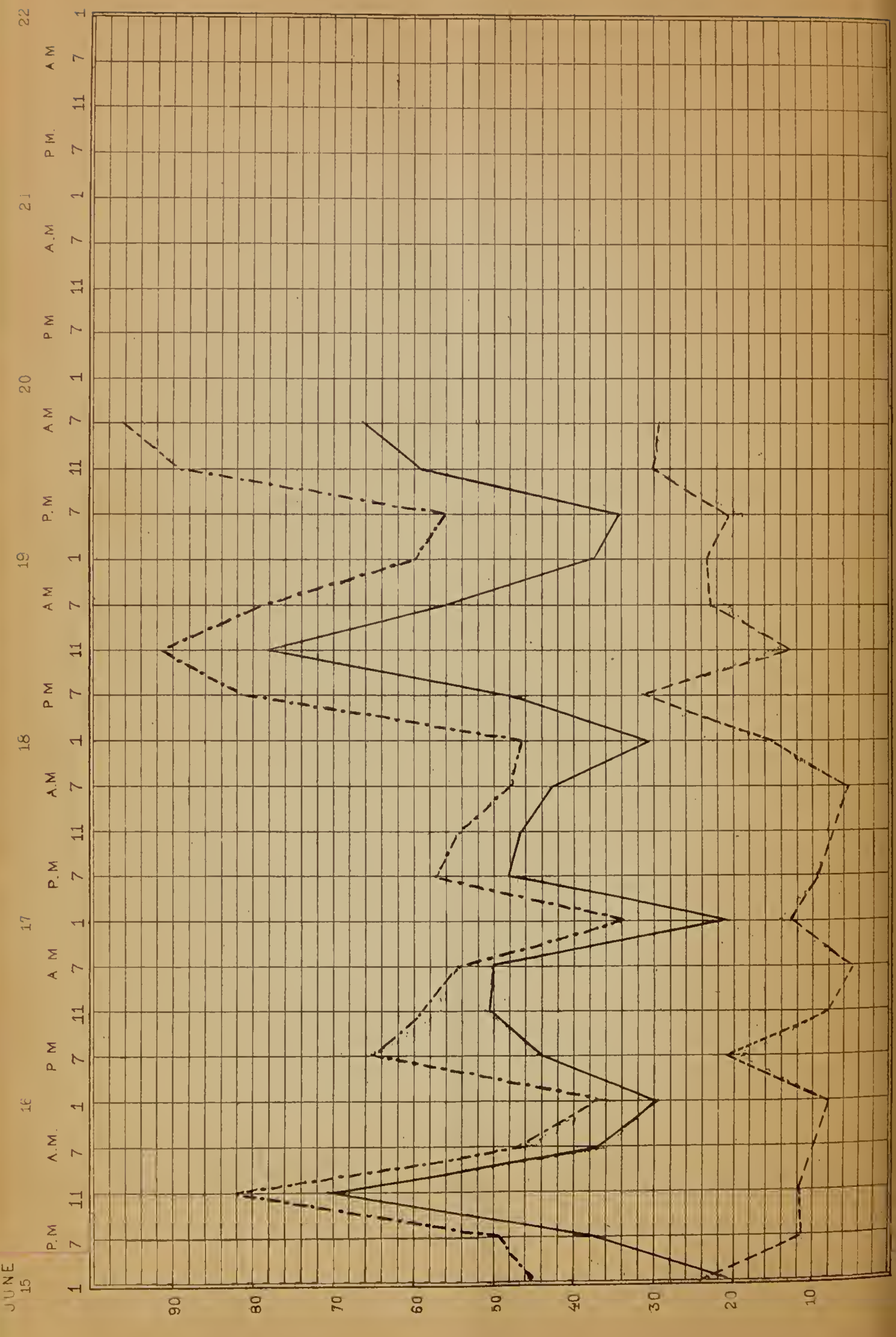

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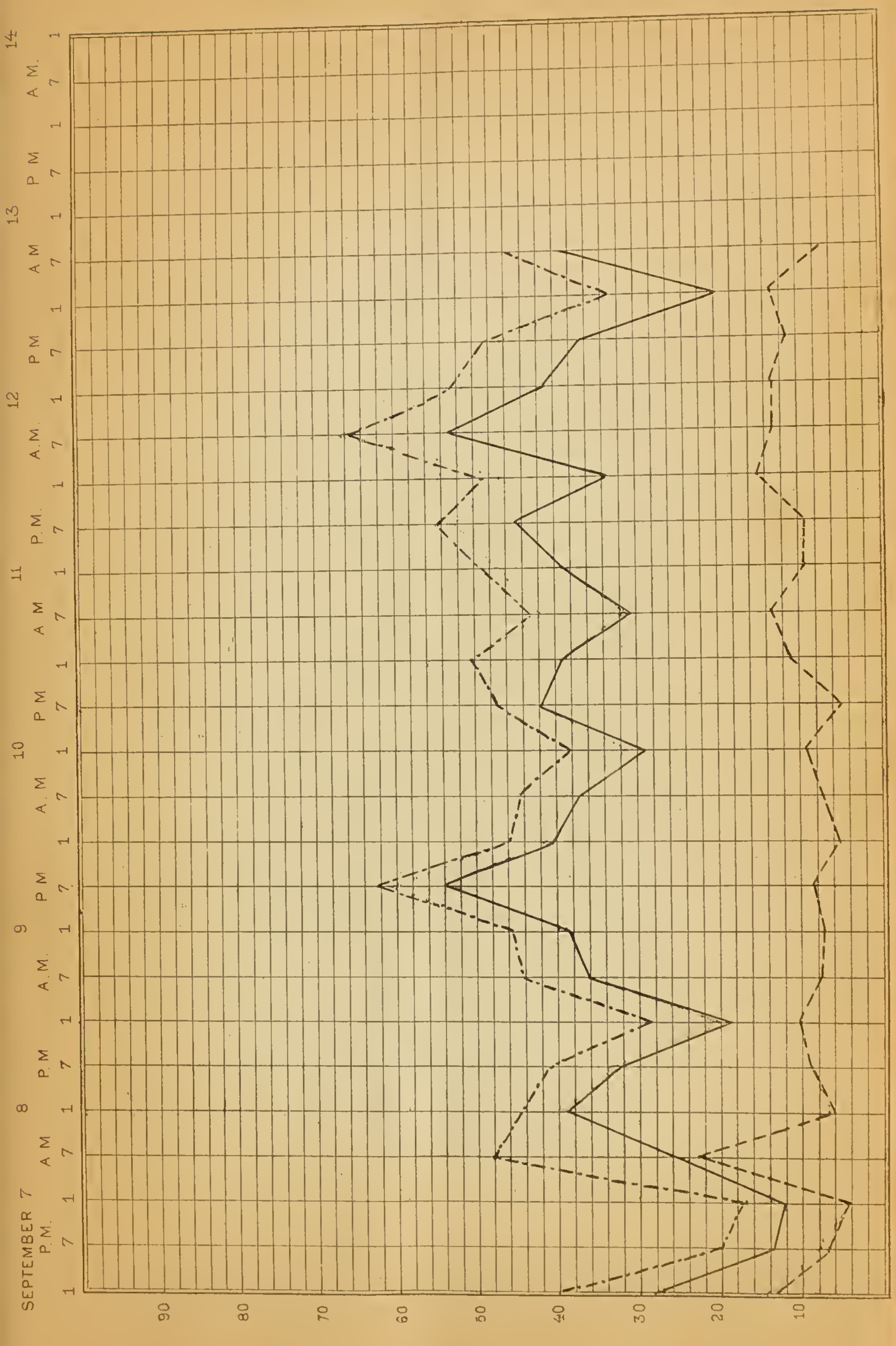

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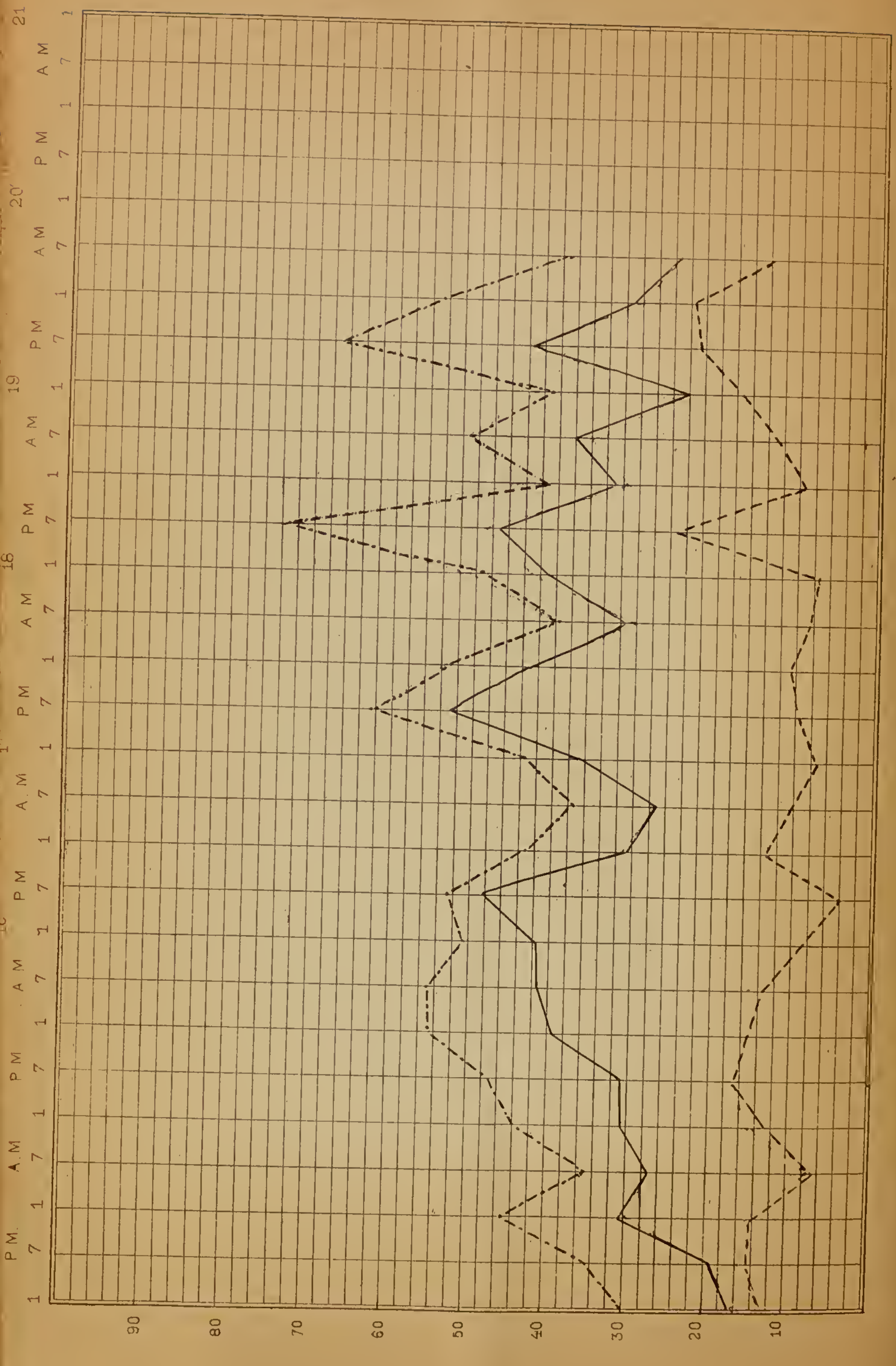
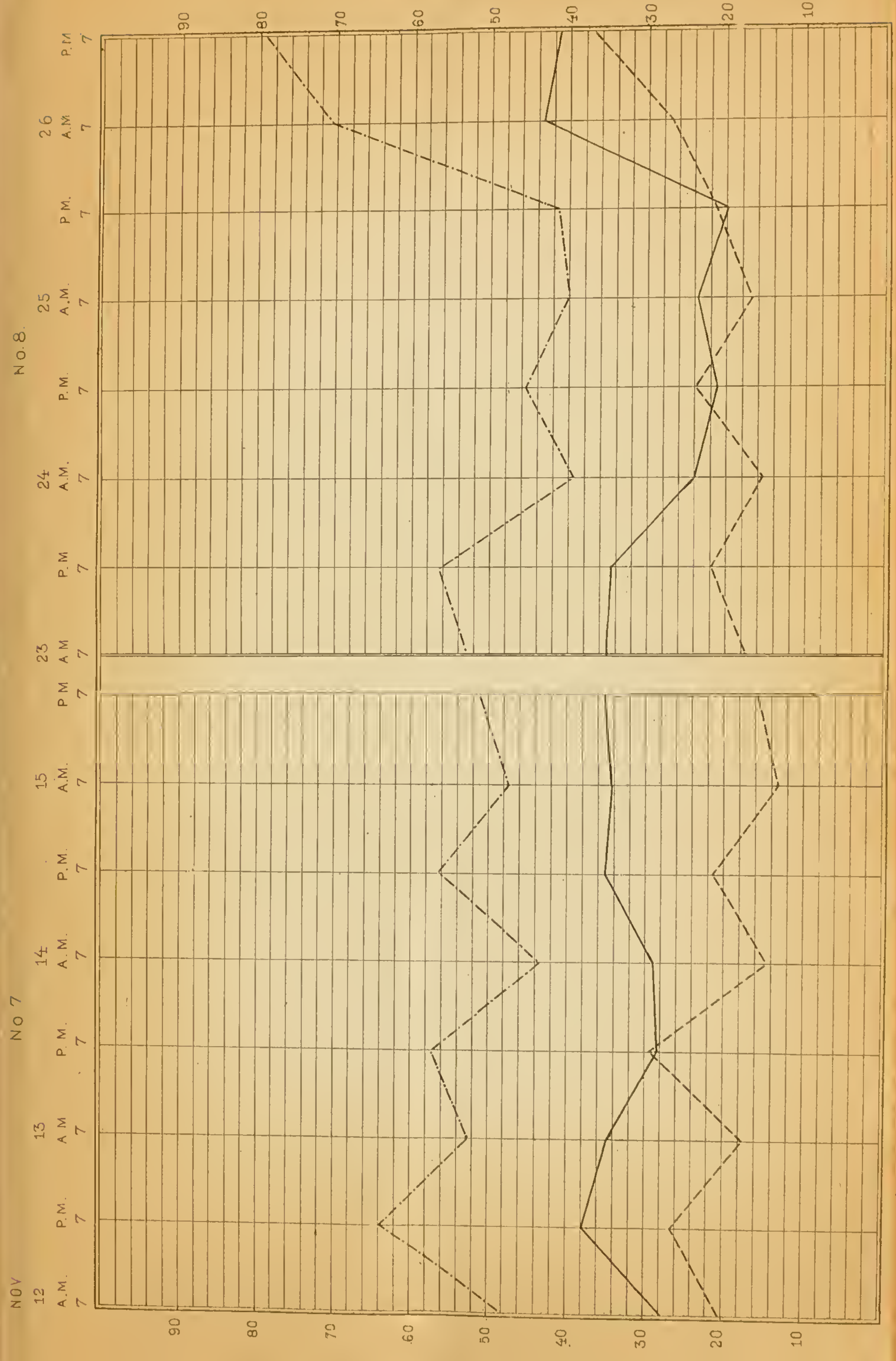


No 7 MIXED DIET, HARD STUDY No 8 MIXED DIET, NO STUDY.



No 9 AVERAGE OF EACH WEEK FOR THE WHOLE SERIES.